Cognitive Systems Engineering in Military Aviation Environments:

Avoiding Cogminutia Fragmentosa!

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Complex environments place workers in an information-rich world with little time to make sense out of events surrounding them, assess their plans, make appropriate decisions, or perform multiple activities. This lack of "cognitive engineering" may produce *cogminutia fragmentosa,* where one's cognitive world breaks down into small, isolated strands of thought as unanticipated events transpire. When this persists, there is no longer an *interface* between the worker's cognitive world and the work for which he is responsible. *Cognitive Systems Engineering* (CSE) has been a response to work environments that produce cogminutia fragmentosa. As cognitive systems are proposed for complex environments, such as in military aviation domains, CSE is frequently utilized to understand and analyze various components of operator expertise and the interaction of expertise with specifications of the work domain.

This report on CSE resulted from an international symposium, Cognitive Systems Engineering in Military Aviation, co-sponsored and organized under the auspices of The Technical Cooperation Program (TTCP). The symposium was held in conjunction with the 9th meeting of TTCP Group HUM (Human Resources and Performance), Technical Panel 7 (TP7) Human Factors in Aircraft Environments, hosted by the U.S. Air Force Research Laboratory (USAFRL) and held in Dayton, Ohio, 22-26 May 2000.

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Preface

Cognitive Systems Engineering (CSE) is making an impact on a number of different domains in which people utilize their various abilities, skills, and knowledge to overcome and change challenging situations. Of contemporary importance is the domain of military aviation. As new challenges are created within this broad community, the need for CSE will become even greater to make a difference in how complex systems come to be used by individual users or crews. The new millennium already is offering a variety of advanced information technologies for military aviation. Coupled with decreasing resources and necessitated reductions in crew size, the role of CSE looms as an extremely relevant field of study—for both theoretical development as well as practical application.

With these ideas in mind, it is our privilege and pleasure to welcome you to an innovative new State-of-the-Art Report (SOAR) that introduces readers to cognitive systems engineering as it relates and applies to military aviation domains. It is our hope to present a broad—yet poignant—integration of perspectives, issues, methods, and applications that afford a first-look understanding of CSE for use within aviation fields of practice. The book will consist of nine distinct chapters that approach CSE in a special way. The chapters are taken from internationally respected authors and provide the reader with a thorough understanding of the foundation of CSE as well as how it relates to different facets of military aviation. As a reader, we believe you will discover an active and illustrative review of the state-of-the-art developments that scientists, engineers, managers, developers, and students must be aware of for furthering their knowledge and understanding. Having introduced our motivations for organizing the book, let's briefly survey the direction the book intends to take.

Complex environments of the 21st century place workers in an information-rich world with little time to make sense out of events surrounding them, assess their plans, make appropriate decisions, or perform multiple activities. In many cases, computational support and advanced interfaces for work activities have not been engineered with cognition or context in mind. Unfortunately, this lack of "cognitive engineering" may produce what we refer to as "cogminutia fragmentosa," where the worker's cognitive world breaks down into small, isolated strands of thought as unanticipated events transpire (mental stovepipes). There can be a loss of meaning or control as the worker becomes separated from the demands of his or her work, and may remain lost in terms of comprehending the emerging elements of a situation. When cogminutia fragmentosa persists, there is no longer an interface between the worker's cognitive world and the work for which he or she is responsible. In other words, the worker cannot properly adapt to the situation encountered (i.e., a maladaptive state exists). If this state continues, errors, failure, and even catastrophic disasters are highly proba-

ble. This state may also contribute to affective and emotional responses (e.g., fear, anxiety, rage), which further complicate agent-environment transactions. However, all is not lost. We are now at a point in history where it is not uncommon to observe human factors practitioners referring to "cognitive systems engineering" as their method or tool of choice to respond to work environments that produce cogminutia fragmentosa. Indeed, as first-of-a-kind cognitive systems are proposed for complex environments, such as in military aviation domains, CSE is frequently utilized to understand and analyze various components of operator or team expertise (e.g., cognitive skills, engagement rules, specific knowledge); and the interaction of expertise with specifications of the work domain. As CSE is applied to real-world settings, agent-environment transactions can be quantitatively or qualitatively modeled (represented) and then used as a basis to predicate elements of a design (e.g., a human-computer interface, a decision support system). Typically, CSE practitioners engage workers through a variety of CSE methods that capture multiple facets of how work is transacted from agents to environment.

This book highlights the perspectives and foundations of an international community of practitioners who have both developed and applied CSE. One can see that the field emerges from several corridors that, in turn, produce alternative methodologies/approaches to address military aviation domains. Differing philosophies and techniques spawn incisive pathways of integration in the development of design artifacts. Because the aviation domain is fraught with multifarious levels of complexity and is demonstrative of cogminutia fragmentosa, we believe it supplies an excellent foundation for reviewing, assessing, communicating, and evaluating some of the principles (and nuances) inherent within various programs of CSE. The SOAR will emulate this objective by presenting the following sections for readers (along with their respective first authors):

- Foundations and Perspectives (Reising, Eggleston, McNeese, Woods)
- Methodological Pursuits (Potter, Neelam, Hendy)
- Innovations, Integration, and Application (Taylor, Hudlicka)

As editors of the book we challenge the reader to contrast/compare philosophies of use, theories of origin, goals, benefits, methods, tools, experiences, constraints and problems of applications, lessons learned, and examples as a means to generate new levels of understanding—as they relate to the specific constraints encountered in military aviation.

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January 2002

About Human Systems IAC

The Human Systems Information Analysis Center (HSIAC) is the gateway to worldwide sources of up-to-date human-factors information and technologies for designers, engineers, researchers, and human-factors specialists. HSIAC provides a variety of products and services to government, industry, and academia promoting the use of ergonomics in the design of human-operated and manned systems.

HSIAC's primary objective is to acquire, analyze, and disseminate timely information about ergonomics. On a cost-recovery basis, HSIAC will perform the following functions—

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- Organize and/or conduct workshops and conferences.

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Foreword

Cognitive Systems Engineering (CSE) theories, methods and their application have received increased attention by human factors and ergonomics professionals who design complex human systems. This is particularly true for the stressful, information-overloaded, time-constrained, lethal work environment within the military. Military aviation is only one of the important domains and is the primary focus of this report. The reasons for this increased emphasis are many and compelling. Most operator-interfaces with complex weapon systems are not designed with the cognitive work requirements of the operators as a formal consideration. Indeed, even the Command, Control, Communications, Computers, (C4), Intelligence, Surveillance and Reconnaisance (ISR) [C4ISR] systems whose sole purpose is to support human situation awareness and decision making are rarely designed from a top-down, human-centered viewpoint. Improperly conceived and interfaced automation can lead to design-induced human error, particularly catastrophic in the aviation domain. This situation will only become exasperated as more uninhabited systems, such as unmanned combat air vehicles, are fielded. This comprehensive report examines in detail the various CSE foundations and theories, practical methods, and finally examples of applications to the design of complex systems. Chapters authored by leading experts in this increasingly important field provide a provocative analysis of progress, successes, and remaining challenges. Differences of opinion are intentionally presented to stimulate a thorough assessment of the state-of-the-art. More development is needed to formalize the methods that can be consistently applied in to bridge the remaining gap between CSE and complex system design. This single report informatively lays out these issues and serves as a guidepost for the way ahead. It is highly recommended reading for CSE researchers striving to mature theories and methods, and designers whose goal is to provide future warfighters with highly effective work-centered systems.

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The SOAR is predicated on and developed, in part, from an international symposium, Cognitive Systems Engineering in Military Aviation, cosponsored and organized under the auspices of the five-nation (United States, United Kingdom, Canada, Australia, New Zealand) forum for international research collaboration, namely The Technical Cooperation Program (TTCP). The symposium was held in conjunction with the 9th Annual Meeting of TTCP Group HUM (Human Resources and Performance), Technical Panel 7 (TP7) Human Factors in Aircraft Environments, hosted by the U.S. Air Force Research Laboratory (AFRL) and held in Dayton, Ohio, 22–26 May 2000. The purpose of TTCP HUM TP7 is to facilitate collaborative research and information exchange on human factors issues relevant to the extension of operational performance of advanced military aircraft. This symposium provided a timely opportunity to bring together key researchers and human factors specialists to discuss recent developments in cognitive systems engineering and to consider the implications for human factors issues in aircraft environments.

The holding of the International Symposium and the year 2000 meeting of the TP–7 Human Factors in Aircraft Systems panel were financially supported by the Crew System Interface Division of the U.S. Air Force Research Laboratory (AFRL/HEC, Mr. Maris Vikmanis, Division Chief).

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